THE NASA ROLE IN MAJOR AREAS OF HUMAN CONCERN

ENVIRONMENTAL QUALITY

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- Prepared by -

Industrial Economics Division
Denver Research Institute
University of Denver
Denver, Colorado 80210

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PREFACE

Understanding the social significance of America's civilian aeronautics and space effort has become increasingly difficult during the past five years. Whereas the missions of the National Aeronautics and Space Administration once figured prominently in discussions of public issues, increased interest in other national priorities has come to compete with, and often to dominate, concern about those missions. The study which generated this presentation was undertaken to facilitate more thoughtful discussion of NASA's activities by exploring how the achievement of mission objectives has contributed to beneficial changes occurring in six areas of major national interest: communication, transportation, environmental quality, safety, health care and work.

This statement focuses attention on the area of environmental quality. After introducing some of the general factors that have affected progress in this area, NASA program elements are examined to illustrate relevant points of contact. Interpretive steps are taken throughout the statement to show a few of the more important ways people's lives have been affected as a result of the work of NASA and other organizations functioning in this area. The principal documents used and interviews conducted are identified after the conclusion of this statement.

This statement, it should be noted, is incomplete in many respects, primarily because it reflects only a small number of the technical, economic, and social forces affecting American life. Taken as a summary statement, however, it hopefully will provide a useful basis for better understanding NASA's role in the national attempt to develop a better environment.

ENVIRONMENTAL QUALITY: THE QUEST FOR GLOBAL IMPROVEMENT

Environmental problems in this country and most other nations of the world have become alarmingly clear during the past decade.[1] Pollution, severe storms, and diminishing energy resources, once thought to be isolated and localized, came to be recognized as matters of global concern. Several environmentalists began to forecast the destruction of modern life if major corrective actions were not soon taken against the technologies producing some of the problems. At the same time, many predictions were made that both natural and man-made environmental problems can and should be solved through the application of comprehensive, systematic, problem-solving techniques.[2] Pessimistic or optimistic though the predictions may have been during the decade, the problems are serious and quite complex, and the steps to be taken to achieve solutions are by no means completely clear.[3]

Complex environmental problems exist on a global scale.

Central to the concern with the environment is the measurement of its present state.[4] Planned change can have meaning only when starting points are known. So, too, the effects of actions taken to reduce the severity of these problems must be measured. Significant advances in both of these measurement areas are occurring in pollution monitoring and abatement; weather observation, prediction and control; and energy resource discovery and conservation.

Critical measurements are necessary for beneficial change.

Several NASA programs impinge on these environmental concerns. At this stage, pollution monitoring, weather prediction, and energy resource management demand social and political decisions to implement change. The techniques for determining the starting points and monitoring progress, however, are being developed rapidly, with aerospace programs generating technology that sometimes plays a vital role.

NASA's monitoring techniques provide needed measurement capability.

Pollution Measurement

The marked increase in public awareness of pollution damage during the 1960's might suggest that such damage reached crisis proportions only recently. Actually, this is not the case at all. Some areas of the world were plagued by pollution problems many years before environmental quality became a matter of continuing, widespread concern. A few scattered incidents, such as the Great Fog of London that killed 4,000 in 1952 and the recent oil spills in this country's waterways, helped focus

The scope and impact of pollution problems change from local to global; the public is more aware.

attention on specific pollution problems. What distinguishes the last ten years from all previous years, however, is the emerging realization that pollution problems are global and that levels of allowable pollution have either already been reached or soon will be.[5]

Many factors stimulate global concern.

A combination of many forces has stimulated concern over global pollution. Ecologists, for example, have made considerable progress in understanding the causes and consequences of different pollutants on land, in waterways and in the atmosphere. Economists and many others have begun to question the environmental impact of industrial growth, particularly the adverse effects of unwanted by-products. At the same time, people everywhere have found it increasingly difficult to escape smog, litter, and contaminated food and water supplies.[6]

Assessment through detection and monitoring is being implemented.

To assess the full impact of pollution, new detection and monitoring equipment and methods have been developed. The importance of such development activity was underscored by the passage of the Federal Air Quality Act of 1967, later strengthened by the Clean Air Amendments of 1970, and with the establishment of the Environmental Protection Agency in 1970. To effectively implement legislation of this type and to determine how serious the problems actually are, new pollution monitoring methods have been adapted to surveying much larger geographic areas than in the past.

While needed pollution monitoring is extensive and diverse, a significant start has been made.

Progress in the development of adequate pollution measurement technology, however, has lagged behind demand. Recently reviewing the total pollution measurement problem, Willis B. Foster, the Environmental Protection Agency's deputy assistant administrator for monitoring, indicated that there is a need to monitor approximately 250 different pollutants, but that only 50 are being monitored because of insufficient funds or inadequate technology.[7] Those being monitored include carbon dioxide; particulate matter; sulfur dioxide; oxides of nitrogen; certain toxic heavy metals; oil; chlorinated hydrocarbons, especially DDT; and certain nutrients. The nationwide air and water pollution monitoring system has grown dramatically in the last five years with rapid increases in the types of regularly monitored pollutants and substantial improvements in the precision and flexibility of various instruments. In addition, the Environmental Protection Agency estimates that the number of scientists and engineers involved in environmental protection activities has risen from roughly 35,000 in 1967 to approximately 70,000; another 170,000 paraprofessionals also are assisting professionals in these activities.[8]

Data generated by monitoring systems have become a significant factor in municipal decisions concerning downtown parking, traffic, public transportation and sewage treatment facilities. Commercial enterprises, from automatic car washes to electric power companies, are installing pollution control equipment now required by law formulated on much of

the same data. The NASA Lewis Research Center is assisting air pollution authorities in Cleveland by analyzing and helping to interpret city-wide data on concentrations of sulfur dioxide, nitrogen oxide and particulates, by devising improved sampling equipment and methods, and by operating a sampling network and performing chemical analyses of trace elements in airborne particles.[9]

Pollution statistics are a factor in governmental and industrial planning and operations.

One of the best indications of just how far pollution monitoring and law enforcement groups have progressed in dealing with various environmental problems was the court order obtained by EPA in November 1971 to shut down specific industrial pollution sources in Birmingham, Alabama. Monitors in that city indicated that the health of the residents was in serious jeopardy because of extremely high levels of air pollution.

The expanding demand for pollution monitoring equipment is indicated by the increasing number of manufacturers identified as producing these items. One industry estimate shows that the number of companies producing water monitoring equipment has quadrupled, and the number manufacturing air monitoring equipment has doubled. Currently, approximately 160 different companies produce monitoring equipment.[10]

Monitoring equipment is being produced commercially.

The Environmental Protection Agency currently supports a broad-scale research and development effort to improve pollution monitoring instruments.[11] The required improvements consist of converting laboratory equipment capabilities to field equipment that is cheap, portable, sensitive, selective, and capable of continuous monitoring. If these requirements are not met, EPA's standards for the various pollutants, pollution alert levels for the public, and the legal enforcement structure for pollution abatement cannot be used to improve the nation's air and water. Through its Technology Application Teams and various field centers, NASA is cooperating with EPA in programs to adapt sensors developed for the space program to help meet these requirements. Some specific programs involving applications of aerospace technology deal with such pollution forms as oil, carbon monoxide, phosphates and nitrates, and sewage.

Research is underway for improved sensing devices.

One example of the use of NASA-developed instrumentation for improving pollution monitoring was recently shown in the Los Angeles Basin. California is presently studying the California aerosol in an attempt to completely characterize it in terms of its physical and chemical properties, its interaction in the atmosphere, and its natural and anthropogenic origins. The results of this study will enhance the California Air Resources Board's capabilities in recommending efficient control strategy for aerosols with the goal of reducing health hazards and improving visibility in major urban centers. NASA's Langley Research Center participated with the State of California in measuring the spatial and temporal distribution of aerosols in the earth's boundary or mixing layer which is contained in the first few thousand

feet above Los Angeles. Langley provided its new 48-inch laser radar and tethered balloon and ground-based particle samplers developed for clear air turbulence (CAT) and other aerospace-related atmospheric programs.[12]

Oil spills in waterways, of course, constitute a major problem in this country and around the world. The results of a study recently sponsored by the Massachusetts Institute of Technology indicate that approximately two million tons of oil are introduced into the oceans each year.[13] The United States has committed itself to a reduction of this pollution; the Coast Guard, in cooperation with Gulf Oil Corporation and other oil companies, is attempting to develop techniques for identifying oils and oil products of different origin. NASA's Ames Research Center has participated with the Coast Guard in a program for detecting and determining the size of oil slicks via sensing devices carried on aircraft and, eventually, satellites.[14] Early detection of oil pollution in waterways allows for countermeasures that will prevent the oil from reaching beach property, likely areas of fish and animal activity, and other locations of commercial and recreational value to the public.

NASA is involved in oil slick detection.

Managing the disposal of municipal and industrial wastes in oceans, lakes and waterways near major metropolitan areas requires monitoring systems that document authorized discharges to verify compliance with regulations, that detect unauthorized dumps or accidental discharges, and that provide data regarding the movement of wastes. Nowhere is the magnitude of this monitoring problem so obvious as in the New York Harbor area into which a variety of wastes are disposed by barge dumping. Such dumping produces surface films and waste fields whose fate and effects are not completely defined. A preliminary analysis of aircraft overflight and ERTS-1 satellite data collected on August 16, 1972, clearly pinpoints the distribution of an acid-waste discharge, a sewage sludge dump, and major sediment inputs into the Harbor area. The data also show the surface drift patterns of waste inputs and water masses at the time of observation.[15]

Aircraft- and satellite-generated data provide information needed to understand environmental effects of marine dumping.

In Florida, the U. S. Geological Survey has used data from aircraft and satellites as part of a thermal pollution study of Biscayne Bay where the hot water effluent from electric power plants is affecting commercial fishing and recreation. The general overview information provided by NASA spacecraft and aircraft has been useful as a new source of pollution data for identifying environmental damage and defining corrective plans.[16]

Overflights produce thermal data to judge water pollution.

Engineers at NASA's Ames Research Center are working closely with the Lieutenant Governor of the State of California in an effort to apply NASA airborne sensing capabilities to environmental and safety problems of the State. The recent Big Sur, California, forest fires were photographed by standard and infrared means from Ames' Earth Resources

Survey aircraft for the purpose of supplying fire fighters with rapid identification of fire activity in remote canyons, locating hotspots, and appraisal of foliage in front of the fire lines. This proved to be invaluable in the counter actions that were employed. The same aircraft are being used in a cooperative program with the State of Arizona on a comprehensive land use analysis experiment.[17]

NASA data assists local agencies with strictly local environmental hazards.

Data gained through remote sensing methods has been close-coupled with local observation in other parts of the nation. For example, using infrared photography from aircraft, NASA's Lewis Research Center recently helped local Environmental Protection Agency and Cleveland officials monitor pollution during the breakdown of Cleveland's Easterly sewage plant.[18] Untreated sewage in waterways posed a transient danger to the public's health; an accurate estimate of its location was most important in issuing the necessary public warnings.

Problems of other government agencies are cooperatively solved using NASA's extensive developmental capability.

Lewis scientists have also helped to develop a new kind of underwater camera system for taking still pictures of algae on the bottom of Lake Erie.[19] The excessive growth of algae in the lake has contributed to the general deterioration of the recreational facilities and to the decline of the commercial fishing industry. Lewis was asked to develop the underwater camera by the EPA's Lake Erie Basin Water Quality Office. The EPA Office employed the underwater camera to observe algae for Project Hypo, a study conducted jointly with the Canadian Centre for Inland Waters.

Air pollution and weather relationships are studied; fogs and showers are traced to pollutant concentrations.

Several research programs are in progress to understand the interaction of pollution and weather. A cooperative research program involving scientists at NASA's Ames Research Center and the University of California was started recently.[20] Scientists are using a series of airborne investigations over the San Francisco Bay and Los Angeles metropolitan areas to trace the photochemical production of pollutants and their atmospheric dispersion. From such research, scientists have determined that the millions of tons of pollutants injected into the lower atmosphere increases the occurrence of fog. Under certain cold atmospheric conditions, pollution can create so-called "freezing nuclei" that help initiate snow or rain by forming ice crystals. Several investigators have noted this effect in causing snow showers downwind from Buffalo, New York. Recently discussing the interaction of weather and pollution, Dr. Charles L. Hosler, dean and professor of meteorology at The Pennsylvania State University, concluded that " . . . our cities on some occasions are causing fogs that help make pollution persist, and that on other days may affect cloud and precipitation patterns. These effects may not all be disastrous, or even undesirable, but they should be better understood so that they might either be eliminated or used to advantage."[21]

Weather Observation and Prediction

Most Americans have come to rely in many ways upon regular, up-to-date information about the weather. By frequent reference to current forecasts, for example, parents often determine how to dress children for school; pilots select the safest routes to their destinations; supervisors arrange appropriate work schedules for outdoor construction crews; and weekend vacationers decide where to go and what to do. These are but a few examples of people's day-to-day reliance on weather information in the United States. Naturally, their reliance on such information becomes far more dramatic when violent storms threaten.

Americans rely personally on daily weather forecasts.

To improve the accuracy and length of weather forecasts, the Federal Government maintains a considerable investment in weather observation, prediction, and control research and development projects. And that investment is paying off. Both the length and the accuracy of local precipitation forecasts, for instance, have increased during the past ten years to the point where the 36-hour predictions of today are as accurate as the 12-hour forecasts issued ten years ago--correct 82 percent of the time.[22]

Longer and more accurate forecasts are increasingly available.

Assuming this trend to longer, more accurate forecasts continues, the National Academy of Science estimates that significantly greater benefits will accrue to weather-sensitive activities: even more efficient management of the routing and scheduling of air, ground and water traffic; decreased spoilage of perishable commodities in transit or at terminal facilities; reduction of unnecessary reseeding, fertilizing or spraying operations; optimum scheduling of the work force, materials and equipment at construction sites; and the application of more efficient methods of facility repair, maintenance, replacement, and switch-over procedures used by the utility industry.[23]

Long-range, reliable forecasts should benefit many industries.

That man stands closer to a better understanding of the weather is in part the result of three technological achievements.[24] First, capabilities have been expanded for observing and measuring weather conditions both on the ground and above the earth's surface. Second, knowledge of the physical processes occurring in the atmosphere has progressed to the point that it can be more accurately quantified and expressed in mathematical models. Finally, the capabilities of high-speed computers have expanded operational ability for handling the very complex numerical models used to describe the atmosphere.

Better understanding of weather is achieved through measuring, modeling and computerizing.

Ever since NASA launched the first weather satellite in 1960, these vehicles have come to play an essential role in the total effort to improve weather forecasting. Satellites provide data concerning cloud

cover and atmospheric temperature conditions over the entire globe. With the assistance of automatic readout systems, meteorologists in 50 different nations are able to use weather satellite photos to augment their forecasting capabilities.[25] Of special utility are weather mosaics of Europe, Asia, Australia, and North and South America. Weather mosaics are assembled from individual satellite photos and transmitted from American ground stations via satellites to receiver countries.

NASA satellites develop global data.

One of the most dramatic benefits accruing from weather satellite programs has been an improved ability to predict severe storms.[26] In conjunction with the Air Force, the Navy, and the National Weather Service, NASA has launched orbiting meteorological satellites that keep full-time watch on potentially dangerous tropical disturbances. The relative effectiveness of these early warning systems, of course, depends a great deal on the ability of a country to disseminate the information properly. The importance of this point can be seen by contrasting the circumstances surrounding Hurricane Camille along the American Gulf Coast in 1969 and the cyclones that struck the coastal areas on the Bay of Bengal in 1970. In the first instance, thousands were warned and took adequate protective cover. In the second case, the capability to act upon the satellite information did not exist, and the result was disaster.

In concert with other federal agencies, NASA provides tools to monitor dangerous storms.

The significant increase in the number of hurricanes detected in the eastern Pacific in recent years is directly related to the expanded observation capability of weather satellites.[27] The region is not part of a major shipping route and so detection of tropical storms has been sporadic in the past. Consequently, the satellite is now considered the number one tool for detecting and tracking tropical cyclones. The director of the National Weather Service Pacific Region Office has stated that satellites constitute the single most important source of data for analyzing and forecasting the weather in the tropical and subtropical Pacific.

Early warning systems and information dissemination help avert disaster.

Though less dramatic than alerting a region to the destructive forces of hurricanes, improved forecasts also are affecting daily life in many other ways.[28] At Kennedy International Airport in New York, for example, weather personnel annotate satellite photos to show pilots the location of storms, fog, snow and clear weather. The same is true in Honolulu, the major hub for trans-Pacific routes. Helpful in predicting jet streams, turbulence, and destination weather, the photos thus aid in the more efficient routing of aircraft and promoting the safety and comfort of passengers. One specific application of satellite weather data in the agricultural industry is in the harvesting of West Coast raisins. These data are

Satellite photos locate storms for aircraft routing and agricultural planning.

used in preparing the weather forecasts that help growers determine the necessity of protecting raisins from rainfall. Satellite data also have been useful in forecasting rainfall for drought-stricken areas and for giving stockmen advance warnings of heavy snowfall.

With expanded satellite coverage of the globe, better information than has ever existed before is now available on weather conditions at sea. Observation at sea has always been difficult because of the inability to maintain permanent surface observation points like those located on land. The United States merchant marine is relying increasingly on satellite-derived data to avoid unfavorable weather and high seas. While computer-generated forecasts were generally successful in pinpointing large-scale winter storms and their accompanying high winds, until recently they tended to be inadequate in the treatment of small-scale storms, particularly those of tropical origin. Now, data concerning smaller storms are fed from satellites into the forecaster's computers, thus making more accurate weather advisories available to shippers.

Global surveillance via satellite now permits forecasting at sea.

The West Coast tuna industry has been able to stabilize its day-to-day rate of catch and decrease search time by using weather satellite photographs.[29] This information is processed by the National Marine Fisheries Service along with information from other sources to determine likely locations of tuna schools. In the Great Lakes, satellite photos are used in preparing ice charts. The Detroit Office of the National Weather Service uses these charts and the latest satellite picture in preparing freeze and thaw forecasts and weekly ice reports. These satellite-aided forecasts serve shippers, drawbridge and lock tenders, water and power plant operators, marinas, and U. S. Coast Guard cutters and icebreakers.[30]

Freeze and thaw forecasts can be made from satellite pictures.

Energy Resource Management

At the basis of America's economic growth and technological progress is an efficient system of energy production and use. This system, however, is in jeopardy because its adverse effect on the natural environment may be in excess of recently tightened protective standards. The by-products of the energy conversion process often are cited for their pollution effects: polluted water from abandoned mines contaminating surface streams; land surfaces stripped bare; fuels spilled into waterways; and combustion products producing air pollution. As though these pollution problems were not enough to produce difficulties for the energy business, a new element has recently emerged that is compounding the energy dilemma: supplies of inexpensive fuel resources are diminishing rapidly.

Conventional energy production is a major source of pollution.

Responses to both the environmental challenges and the problem of diminishing resources are being formulated on many fronts. Congressional

subcommittees have initiated studies of different elements of these problems; industry and government are cooperating in research and development projects aimed at developing new, pollution-free sources of energy; and industry and the Federal Power Commission are assembling information that will be used for shaping national energy policy. Worldwide discussions are underway, sponsored by the United Nations and several scientific groups.[31]

The energy problem is being studied to develop adequate national policy.

Since most of the readily discoverable energy reserves have already been located, society must develop technology that will yield better information for locating the energy resources needed to sustain progress. Aerospace is helping to provide some of the newer means currently available. Remote sensing of earth resources until recently was performed by aircraft equipped with special sensing tools; the need now is for global satellite surveys that give much broader pictures of the world's energy resource inventory.

Aerospace technology is facilitating the discovery of new energy resources.

To this end, an earth resources program conducted by aircraft and satellite has been underway since 1968. The NASA overflight program has developed the equipment and techniques needed to recognize many geologic features from high altitude aircraft. The aircraft overflight program was preparatory for the first Earth Resources Technology Satellite (ERTS-1) launched successfully in July 1972 and for the 1973 launching of Skylab, the first manned space station. Tests of both satellite and aircraft sensors are yielding clues to geologic formations normally associated with oil and gas deposits. Discovery of new supplies should help reduce the burden of diminishing energy resources currently affecting the country.

The most serious impacts of energy's interactions with the environment occur when fuel is transformed into useful power. To help solve this problem relatively pollution-free gas turbine engines developed initially for military and civilian aerospace applications have been adapted for use in electric power production.[32] Many generating systems around the world employ gas turbines as sources of electric power, especially during periods of peak demand.[33]

Relatively pollution-free gas turbine engines are generating electricity.

In addition to its work on gas turbines, NASA also has pioneered in the development of fuel cells, batteries and solar energy systems.[34] Commercial applications of fuel cells are expanding rapidly.[35] Pratt and Whitney Aircraft, which developed fuel cells for Apollo, is working with a combine of 35 utility companies in a major effort to develop fuel cells commercially. One of the main advantages of fuel cells is that they are at least ten times cleaner in terms of air pollution than standard fossil fuel, steam-electric generating plants; they also offer major improvement over other types of energy generation by producing less water and noise pollution. Nearly 60 of the Pratt-Whitney units were installed for experimental purposes during 1971 and 1972 at 30 locations across the country to provide

on-site electricity for commercial, hospital, office building and residential uses.[36] As these and other experimental fuel cell power plants now being planned become operational, they can play a major role in conserving natural resources and reducing pollution.

Having met space program requirements for small, powerful, reliable batteries, manufacturers are finding new applications for similar batteries in cordless household appliances, electric razors and toothbrushes, toys, flashlights and photographic electronic flash units. Solar cell power systems are primarily used in weather and communication satellites. According to Dr. Erich A. Farber, director of the University of Florida Solar Energy and Energy Conversion Laboratory, solar cells have been used to monitor solar radiation at government and private weather stations, to supply power for the U. S. Forest Service remote weather stations, to run remote lighthouses, and to operate telephones in areas removed from ordinary service systems.[37] Most of these applications use the cells in conjunction with the batteries mentioned above. When used to measure solar radiation, solar cells cost less than one-tenth of the amount required for previously used instruments and give the same quality of information on the daily total of radiation. Many of the cells used in such applications are available from manufacturers as space program rejects that failed the rigid quality control specifications set for space-bound hardware.

In remote areas, solar cells and batteries provide an attractive energy alternative.

As part of President Nixon's stated intention that NASA work on the problem of providing the nation with clean electrical energy, aerospace researchers at the Lewis Research Center are examining the engineering possibilities for directly converting solar energy to electricity for terrestrial uses.[38] In an even broader effort, dating from September 1968, Lewis personnel have developed and maintained close working relations with the electric power industry for the purpose of transferring important technology from aerospace to that industry.[39]

The key energy problems contributing to pollution and diminishing supplies probably will remain unresolved for years to come. The delay in development of nuclear power has added problems to the already aggravated ones of dwindling fossil fuels. New technologies affecting energy discovery, processing, and conversion, however, will go a long way toward alleviating those problems, thus giving man added time to come up with adequate solutions.

Pollution problems associated with power generation will not be solved quickly.

Observation: Only the Beginning

The challenges of space and of other national objectives have helped to produce a body of technology that bears on the solution of many environmental quality problems. Some examples of major changes that are occurring through application of aerospace technology to

environmental problems include new developments in pollution and weather monitoring instruments and systems; new pollution control equipment and techniques; continuing discovery of fundamental relationships between environmental parameters based on improved information; and tremendous increases in the data available to earth scientists for use in resource management and environmental protection programs.

Aerospace technology is used extensively in attacking environmental measurement problems.

The special needs of man-in-space have helped in formulating solutions to the environmental problems of man-on-earth. From surveying the extent of water pollution to aiding in the preparation of weather forecasts, aerospace technology has been used to analyze various problems afflicting the environment. In addition, important social and legal changes are occurring in anticipation of the information that will be sent back to earth by the earth resources satellites. For example, to comply with recently approved legislation, the State of New Jersey is using data generated by the ERTS-1 satellite, along with information from aircraft and other sources, to map its coastal lands.[40] As this and similar mapping activities proceed, cartographers will be better able to present precise shapes of land masses and water bodies. In addition to assisting in mapping activities, photos taken from other satellites have been used to identify ice floes in Hudson Bay, forest fires in Alaska, and land use patterns in the San Francisco Bay area.[41]

From the perspective of space more detailed and expansive views of Earth are possible.

Pollution, weather, and earth resource monitoring is a young technology dependent for its improvement on a number of factors: setting meaningful standards, specifying elements to measure, and perfecting sophisticated instruments that accurately and economically measure those elements.[42] Without such technology, control is impossible. What the intensive and divergent examples reviewed here suggest, however, is that the needed environmental measurement technology is being developed and that NASA has been contributing substantially to the development effort.

REFERENCES

1. Council on Environmental Quality. Environmental Quality: The Third Annual Report of the Council on Environmental Quality. Washington, D. C.: Government Printing Office, August 1972, Chapters 3 and 4.

2. Massachusetts Institute of Technology. Man's Impact on the Global Environment: Assessment and Recommendations for Action. A report of the Study of Critical Environmental Problems. Cambridge, Massachusetts: 1970, p. 4.

3. American Chemical Society. Cleaning Our Environment: The Chemical Basis for Action. A Report by the Subcommittee on Environmental Improvement, Committee on Chemistry and Public Affairs. Washington, D. C.: 1969, Introduction.

4. Council on Environmental Quality. Op. cit., p. 3.

5. Massachusetts Institute of Technology. Op. cit.

6. Church, George J. "Can the World Survive Economic Growth?" Time, August 14, 1972, pp. 56-7.

7. Foster, Willis B. Deputy Assistant Administrator for Monitoring, U. S. Environmental Protection Agency, Washington, D. C. Telephone interview on February 14, 1973.

8. Parsons, William B. Assistant Director for Manpower Forecasting and Professional Training. Office of Education and Manpower Planning. U. S. Environmental Protection Agency. Telephone interview on February 15, 1973.

9. Lundin, Bruce T. Director, NASA Lewis Research Center, Cleveland, Ohio. Personal correspondence on November 17, 1972.

10. Chilton Company. Instruments and Control Systems: 1972 Buyers' Guide. Bala-Cynwood, Pennsylvania: 1972.

11. Foster, Willis B. Op. cit.

12. Cortright, Edgar M. Director, NASA Langley Research Center, Hampton, Virginia. Personal correspondence on November 29, 1972.

13. Massachusetts Institute of Technology. Op. cit., p. 139.

14. NASA Ames Research Center. "Method to Detect Oil Slicks Found," Ames Release 71-9. Mountain View, California: March 25, 1971.

15. Clark, John F. Director, NASA Goddard Space Flight Center, Greenbelt, Maryland. Personal correspondence on December 17, 1972.

16. Kolipinski, Dr. M. C. United States Geological Survey, Miami, Florida. Telephone interview on January 5, 1972.

17. Mark, Hans. Director, NASA Ames Research Center, Moffett Field, California. Personal correspondence on November 29, 1972.

18. Olson, Walter T. "Space Exploration and the Quality of Life," Isotopics, October 1971, pp. 9, 14.

19. NASA Lewis Research Center. "News," Lewis Release 71-16. Cleveland, Ohio: April 16, 1971.

20. NASA Ames Research Center. "Space Technology to Aid Smog Research," Ames Release 71-18. Mountain View, California: June 20, 1971.

21. Hosler, Charles L. "Inadvertent Weather Modification," in University of Denver, Western Resources Conference 1970: Urban Demands on Natural Resources. Denver, Colorado: 1970, pp. 17-20.

22. Cressman, George P. A Century of Weather Progress. American Meterological Society, 1970, pp. 71-7.

23. National Academy of Sciences, National Research Council. Useful Applications of Earth-Oriented Satellites. Summaries of Panel Reports from Summer Study on Space Applications. Washington, D. C.: 1969, p. 18.

24. Lusignan, Bruce, and John Kiely (eds). Global Weather Prediction, the Coming Revolution. New York: Holt, Rinehard and Winston, Inc., 197, pp. 12-3.

25. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite Service. First Five Years of Environmental Satellite Service: An Assessment. Washington, D. C.: February, 1971, p. 26.

26. "Toward Hurricane Surveillance and Control," Technology Review, October/November 1971, pp. 59-66.

27. Bottoms, Jack. Director, Pacific Region Office, National Weather Service, San Francisco, California. Telephone interview on October 5, 1971.

28. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite Service. Op. cit., pp. 9-11, 14.

29. Felando, Augusta. American Tuna Boat Association, San Diego, California. Telephone interview on October 6, 1971.

30. U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite Service. Op. cit., p. 20.

31. Schanz, John J. Director, Future Requirement Agency, Denver Research Institute, University of Denver, Denver, Colorado. Personal interview on February 15, 1973.

32. "Gas Turbines in Utility Power Generation," Gas Turbine International, January/February 1971, pp. 18-9.

33. Robbins, Martin D., John A. Kelley, and Linda Elliott. Mission-Oriented R&D and the Advancement of Technology: The Impact of NASA Contributions. Volume Two. Denver, Colorado: Denver Research Institute, University of Denver, May 1972, pp. 171-2.

34. Stanford Research Institute. Impacts of New Materials Technology: Volume IV of Some Major Impacts of the National Space Program. Aerospace Systems Service. Menlo Park, California: June 1968, pp. 5-6.

35. "Natural Gas Fuel-Cell Power Plant Start of New Energy Use," Oil Daily News, May 20, 1971.

36. Cox, John A. Public relations officer, Pratt and Whitney Aircraft Division, United Aircraft Corporation, Hartford, Connecticut. Telephone interview on February 15, 1973.

37. Farber, Erich A. Director, Solar Energy and Energy Conversion Laboratory, University of Florida, Gainesville, Florida. Telephone interview on February 24, 1972.

38. Lundin, Bruce T. Op. cit.

39. National Aeronautics and Space Administration. Selected Technology for the Electric Power Industry. NASA SP-5057. Washington, D. C.: 1968.

40. Stitt, Jo Ann. Environmental Specialist, Department of Environmental Protection, State of New Jersey, Trenton, New Jersey. Telephone interview on February 15, 1973.

41. McCann, William D. "Resource Satellite Bring NASA Myriad Surprises," Plain Dealer, Cleveland, Ohio, September 4, 1972.

42. Ford, Barbara, "Environmental Monitoring," Design and Environment, November 28, 1972, p. 59.